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Original Research

The efficiency of deep learning for the diagnosis of psammomatous meningioma

Deep learning and psammomatous meningioma

Syed Usama Khalid Bukhari[1], Asmara Syed[3], Syed Khuzaima Arslan Bokhari[2], Syed Sajid Hussain Shah[3]
[1]Department of Computer Science, The University of Lahore, Islamabad, Pakistan
[2]Pediatric medicine, Doctors hospital, Lahore, Pakistan
[3]Faculty of Medicine, Northern Border University, Arar, Kingdom of Saudi Arabia

Abstract

Aim: The study aims to assess the efficiency of deep machine learning (convolutional neural network architecture) for the diagnosis of psammomatous meningioma by evaluating the digital pathology images.

Materials and Methods: A total of three hundred and twenty (320) digital images have been acquired from the anonymized hematoxylin and eosin-stained slides, which included 161 images of Psammomatous Meningioma and 159 images of normal intracranial tissue. The dataset was divided into a train set, 80% of the entire data, and 20% into the test data set. ResNet-18 architecture (state of the art deep learning computer vision algorithms) is used to diagnose these cases.

Results: A total of 161 images of psammomatous meningioma and 159 images of normal tissue are used; 80% of the collected data was used for training, where 20% for testing purposes. Using deep learning, we achieved 98.79 F1-Score and 98.4% accuracy.

Discussion: The advancement in the field of artificial intelligence has opened a lot of new channels and generated new opportunities to develop computer-aided diagnostic systems. The applications of machine learning have revealed promising results for the histopathological evaluation of neoplastic lesions. In the present study, the excellent diagnostic accuracy (98.4 %) has been achieved with the convolutional neural network architecture. There was an F1-score of 98.79 for the diagnosis of psammomatous meningioma in the present series. The studies conducted for the diagnosis of breast cancer metastasis, lung carcinoma, prostatic malignant tumors, and basal cell carcinoma also revealed excellent results.

Convolutional neural network (CNN) architecture is emerging as a quite efficient deep machine learning tool for the analysis of the pathology images. This technology may be quite a valuable adjunct tool in diagnostic surgical pathology.

Keywords

Psammomatous meningioma; Histopathological diagnosis; Deep learning

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Corresponding Author: Syed Usama Khalid Bukhari, Department of Computer Science, The University of Lahore, Islamabad, Pakistan.
E-mail: usama.khalid@cs.uol.edu.pk P: +92 349 1050 449
Corresponding Author ORCID ID: https://orcid.org/0000-0003-1581-8609

Introduction

Among the primary intracranial neoplasms, meningiomas are the most frequent type of tumors [1-2]. Meningiomas are more common in females as compared to males [3]. However, the research data has revealed that the risk of death due to meningioma is lower in female patients than in male patients [4]. A rising trend in the incidence of meningioma has been observed over the past few years in many countries, which may be attributed to the increasing aged population and better availability of diagnostic and health facilities [5]. The risk factors of meningioma include ethnicity, history of allergy, gender, family history, genetic polymorphism, ionizing radiation, nutrition, and reproductive history. Some of these factors may also be a contributing factor in the increase in the incidence of these tumors [5]. The majority of meningiomas fall in the category of grade 1[6-7].

The histological variants of grade 1 meningioma are transitional, meningothelial, psammomatous, fibrous, microcystic, secretory, lymphoplasmacyte rich, angiomatous, and metaplastic [1]. The psammomatous meningioma is characterized by the presence of psammoma bodies, which are calcified masses. In certain tumors, the psammoma bodies are numerous, and the intervening meningothelial cells are less in quantity. The presence of characteristic calcified structure (psammoma bodies) makes the diagnosis of this subtype of meningioma relatively easy. Because of this characteristic visual pattern of this lesion, it would be essential to develop computer vision-based programs to diagnose such type of lesion to assist the health professionals in patient care.

The histopathological assessment of the biopsy specimen is vital for the conclusive diagnosis of tumors, which includes the fixation, processing, cutting, staining, and microscopic examination of the tissue sections. The histological assessment of tissue sections requires a lot of expertise in the field of histopathology. The increasing number of tumor biopsies with relatively less availability of consultant histopathologists requires assistance from artificial intelligence. The digitalization of pathology slides has made it easier to apply deep machine learning technology, particularly CNN, for the histopathological evaluation of digital images of various lesions.

The main aim of the present research project is to assess the efficiency of CNN for the diagnosis of psammomatous meningioma.

Material and Methods

This study has been conducted after getting ethical approval from the University of Lahore - Islamabad Campus. A total of three hundred and twenty (320) digital anonymized images have been acquired from the anonymized slides stained with hematoxylin and eosin stain, which included 161 images of Psammomatous Meningioma and 159 images of normal intracranial tissue. The dataset was divided into a train set, 80% of the entire data, and 20% into the test data set.

We have used ResNet-18 architectures. We used the transfer learning approach; the pre-trained ResNet18 on ImageNet data set [8] was used to avoid the limitation of the small dataset we manage to obtain. A total of 161 images of Meningioma and 159 images of normal tissue were used. These images have been reviewed and labeled by two histopathologists.

A random approach of FastAI API is used to load the data into train and test sets to avoid the chances of images of the same class been selected for a mini-batch input that can harm the performance of model validation. The entire dataset has been split into training and test sets. For training, 80% of the entire dataset was used, where for testing, 20% of the total dataset was used. For image, we used data augmentation for regulation.

Results

A total of three hundred and twenty (320) images were collected; one hundred and sixty-one images (161) of Meningioma and One hundred and fifty-nine (159) images of normal tissue. Two hundred and fifty-six (256) images were randomly chosen from both Meningioma and normal tissue images, 80% of the total data set and were employed for training data set. While sixty-four (64) images were randomly chosen from both Meningioma and normal tissue images, 20% of the data set was employed in the test data set. ResNet -18 architecture was used to classify the input image. Accuracy of 98.4 % and F1-score of 98.79 were obtained on the entire data set. ResNet implementation of FastAPI was used, on intel-i5 PC with RTX-2070 GPU.

Table 1. Parameters for image augmentation

horizontal_flip	True
vertical_flip	False
max_rotate	10.0
max_zoom	1.1
max_lighting	0.2
max_warp	0.2
p_affine	0.75
p_lighting	0.75
Image Size	224
Normalize	*Normalize using ImageNet*

Table 2. Detailed results of train and test data set

Train Data			
Algorithm	Precision	Recall	F-1 Score
ResNet-18	0.992	0.992	0.992
Test Data			
Algorithm	Precision	Recall	F-1 Score
ResNet-18	1.0	0.967	0.983

Discussion

The accurate and rapid diagnosis of tumors plays a significant role in the management of patients suffering from neoplastic lesions. The conclusive diagnosis depends upon the critical and meticulously evaluation of biopsies from the tumors, which involves the critical step of microscopic examination. Based on characteristic microscopic features, the histopathologists make a critical decision regarding the diagnosis of these tumors. Any judgmental or interpretational error in the histopathology may reveal disastrous results in patient health care and may also result in litigations. The exhaustive and extensive work causes fatigability, which may be a significant cause of human errors. The rising trend in the prevalence of tumors is expected to contribute to the chance of errors to be more, which would be a

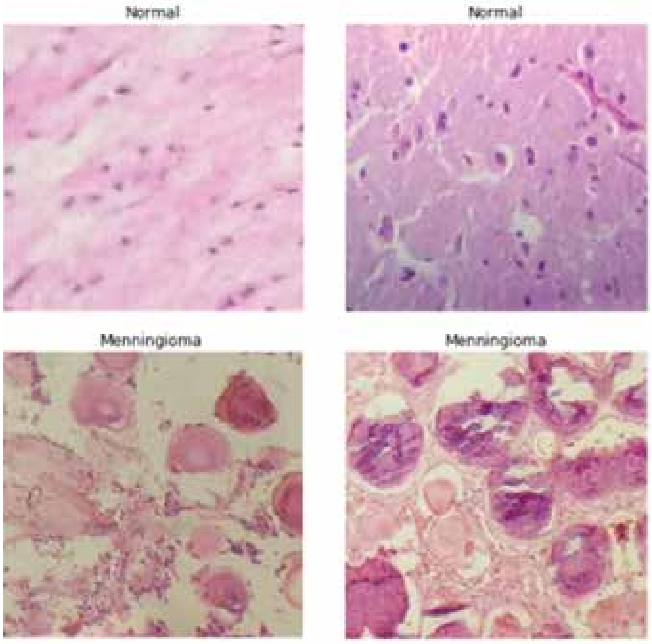

Figure 1. Data bunch generated by FastAI API to show that it loaded the images and labelled correctly

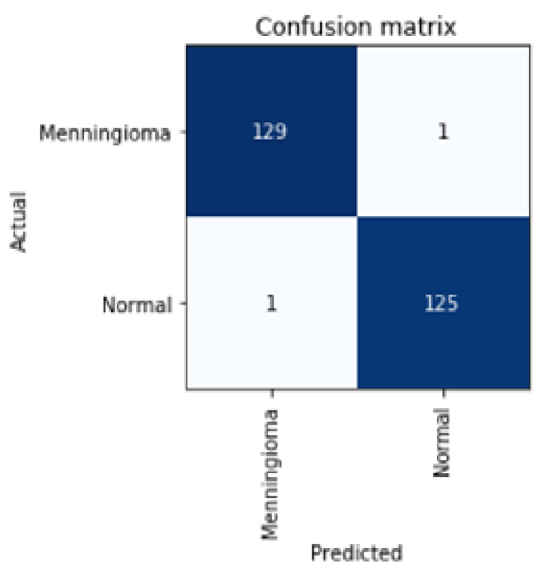

Figure 2(a). Confusion Matrix of training data

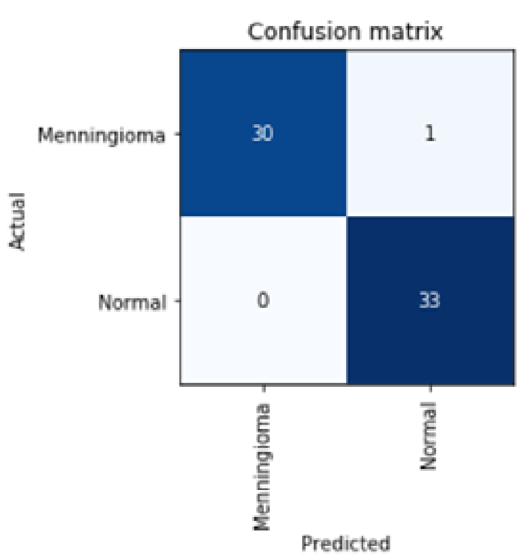

Figure 2(b). Confusion Matrix of test data

significant challenge in the near future. The automation and computer-aided systems with the help of artificial intelligence algorithms may help reduce the burden of histopathological evaluation of biopsies as these may reduce the chance of human errors due to fatigability and may also improve the speed of decision-making process. In the present decade, deep learning technology has made it possible to make computer-aided systems that could assist in the histopathological assessment of biopsy specimens.

The availability of high-resolution image data of various pathological lesions, including malignancies, has made it possible to develop machine learning algorithms based on characteristics and distinguishing features and pattern of neoplastic lesions by extracting these features.

The progressive growth in the computational pathology with the advancement in artificial intelligence has paved the way for a more precise and better assessment of features present in the images for categorization, classification, and diagnosis. One of the critical subsets of artificial intelligence is deep machine learning. In deep learning technology, the convolutional neural network (CNN) architecture is commonly used to analyze digital images [9]. There are three main components of a convolutional neural network. It includes the input layer along with a large number of hidden layers, and the third component consists of the output layer [10].

The present study performed on the digital histopathological images for the diagnosis of psammomatous meningioma by applying convolutional neural network architecture revealed the diagnostic accuracy of 98.4 % and F1-score of 98.79. A closely similar diagnostic accuracy has been observed in the studies conducted for the diagnosis of breast cancer metastasis, lung carcinoma, prostatic malignant tumors, and basal cell carcinoma [11-13].

The deep machine learning technique is yielding promising results for the diagnosis of different types of cancers. The development of such tools will be a great help to the histopathologists in rendering better diagnostic services, which has got paramount importance in the healthcare system. The computational histopathology will reduce the chance of inter-observer discrepancies and improve diagnostic laboratories' efficiency by decreasing the time of the biopsies for the final diagnosis. The application of computer vision-based programs for the diagnosis of malignancies will also reduce the chance of human errors due to fatigability. The diagnostic errors in pathology have an impact on patient care prognosis [14]. With the help of artificial intelligence, the mistakes can be reduced in the laboratory. In the near future, the application of machine learning (artificial intelligence) may be able to play a more influential role in health care and the capability to transform patient care [15].

Further research is recommended for the assessment of deep machine learning as a useful adjunct tool for the histopathological diagnosis of various types of neoplastic lesions.

Conclusion: The application of deep machine learning as a tool for the analysis of the pathology images has been emerging as an efficient technique. This technology may be quite a valuable adjunct tool in the diagnostic surgical pathology.

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Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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References
1. Buerki RA, Horbinski CM, Kruser T, Horowitz PM, James CD, Lukas RV. An overview of meningiomas. Future Oncol. 2018;14(21):2161-77. DOI: 10.2217/fon-2018-0006.
2. Almutrafi A, Bashawry Y, AlShakweer W, Al-Harbi M, Altwairgi A, Al-Dandan S. The Epidemiology of Primary Central Nervous System Tumors at the National Neurologic Institute in Saudi Arabia: A Ten-Year Single-Institution Study. J Cancer Epidemiol. 2020;2020:1429615. DOI:10.1155/2020/1429615.
3. Shah S, Rehman L, Ahmed N, Chaudhry MA. Surgical outcome of meningioma of brain tumours. Pakistan Journal of Medical and Health Sciences. 2015;9(3):1086-7.
4. Yang A I, Mensah-Brown K G, Rinehart C, Fathy R, Hitti FL, Brant J, et al. Inequalities in Meningioma Survival: Results from the National Cancer Database. Cureus. 2020: 12(3): e7304. DOI: 10.7759/cureus.7304.
5. Baldi I, Engelhardt J, Bonnet C, Bauchet L, Berteaud E, Gruber A, et al. Epidemiology of meningiomas. Neurochirurgie. 2018;64(1):5-14. DOI: 10.1016/j.neuchi.2014.05.006.
6. Assi HI, Hilal L, Abu-Gheida I, Berro J, Sukhon F, Skaf G, et al. Demographics and outcomes of meningioma patients treated at a tertiary care center in the Middle East. Clin Neurol Neurosurg. 2020;195:105846. DOI: 10.1016/j.clineuro.2020.105846.
7. Ostrom QT, Gittleman H, Xu J, Kromer C, Wolinnsky Y, Kruchko C, et al. CBTRUS statistical report: primary brain and other central nervous system tumors diagnosed in the United States in 2009–2013. Neuro Oncol. 2016; 18(Suppl. 5); S1–75 . DOI: 10.1093/neuonc/now207.
8. Russakovsky O, Deng J, Su H, Krause J, Satheesh S, Ma S, et al. ImageNet Large Scale Visual Recognition Challenge. Int J Comput Vis. 2015; 115:211-52. DOI:10.1007/s11263-015-0816-y.
9. Chang HY, Jung CK, Woo JI, Lee S, Cho J, Kim SW, et al. Artificial Intelligence in Pathology. J Pathol Transl Med. 2019;53(1):1-12. DOI: 10.4132/jptm.2018.12.16.
10. Janowczyk A, Madabhushi A. Deep learning for digital pathology image analysis: A comprehensive tutorial with selected use cases. J Pathol Inform. 2016;7:29. DOI:10.4103/2153-3539.186902.
11. Ehteshami Bejnordi B, Veta M, Johannes van Diest P, van Ginneken B, Karssemeijer N, Litjens G, et al. Diagnostic assessment of deep learning algorithms for detection of lymph node metastases in women with breast cancer. JAMA. 2017;318(22):2199-2210. DOI: 10.1001/jama.2017.14585.
12. Campanella G, Hanna MG, Geneslaw L, Miraflor A, Silva VWK, Busam KJ, et al. Clinical-grade computational pathology using weakly supervised deep learning on whole slide images. Nat Med. 2019; 25: 1301–9. DOI: 10.1038/s41591-019-0508-1.
13. Coudray N, Ocampo PS, Sakellaropoulos T, Narula N, Snuderl M, Fenyo D, et al. Classification and mutation prediction from non-small cell lung cancer histopathology images using deep learning. Nat Med. 2018; 24: 1559–67. DOI: 10.1038/s41591-018-0177-5.
14. Santana MF, Ferreira LCL. Diagnostic errors in surgical pathology. J Bras Patol Med Lab. 2017;53 (2):124-9.
15. Rashidi HH, Tran NK, Betts EV, Howell LP, Green R. Artificial Intelligence and Machine Learning in Pathology: The Present Landscape of Supervised Methods. Acad Pathol. 2019;6. DOI: 10.1177/2374289519873088.

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